Behaviour of pre-pubertal gilts and its relationship to farrowing behaviour in conventional farrowing crates and loose-housed pens

Ison, SH; Wood, CM; Baxter, EM

Published in:
Applied Animal Behaviour Science

DOI:
10.1016/j.applanim.2015.06.004

First published: 01/01/2015

Document Version
Peer reviewed version

Highlights

- The ability to select gilts to perform well in free-farrowing systems would be a major advantage.
- This study investigated gilt behaviour in pre-pubertal temperament tests (human interaction and startle/novel object tests) and farrowing behaviour in a loose-farrowing system and conventional farrowing crates.
- Gilt behaviour in pre-pubertal tests was influenced by first test type experienced.
- Piglet-directed aggression at farrowing was lower in loose-farrowing pens compared with conventional crates.
- Gilts showing severe piglet-directed aggression at farrowing tended to make more contact with the human and the object during the first pre-pubertal test.
- Gilts that crushed one or more piglets were slower to contact the human and the object during the first pre-pubertal test.

Behaviour of pre-pubertal gilts and its relationship to farrowing behaviour in conventional farrowing crates and loose-housed pens

Sarah H. Ison[a,*], Cynthia M. Wood[b] and Emma M. Baxter[a]

[a]Scotland's Rural College (SRUC), Animal Behaviour & Welfare, Animal & Veterinary Sciences Group, Roslin Institute Building, Easter Bush, Midlothian EH25 9RG

[b]Virginia Polytechnic Institute and State University, Department of Animal and Poultry Sciences, Blacksburg 24061

*Corresponding author:

Email: Sarah.Ison@sruc.ac.uk

Tel: +44 (0)131 6519292

Fax: +44 (0)131 5353121

ABSTRACT

Individual variation in the reproductive performance of sows has the potential for greater negative impacts in loose-farrowing systems. Therefore, the ability to select gilts that will perform well would be a major advantage. This study investigated the behaviour of gilts during pre-pubertal tests and farrowing behaviour in conventional crates and PigSAFE (Piglet and Sow Alternative Farrowing Environment) pens. Gilts underwent two phases of behavioural testing. Firstly, gilts were subjected to three individual human interaction and three startle object tests randomly allocated to test sessions over 3 days (i.e. gilts had either a human or startle test first). Three weeks later, gilts underwent three human interaction and three novel object tests, in their stable group of six. Gilts farrowed in individual PigSAFE pens or conventional crates and behaviour was observed for 8 hours from the first piglet birth. Data were analysed using linear mixed models and Spearman's rank correlations. A novel finding was the effect of individual test order: gilts that had the human interaction or startle object test first behaved differently. The first test was different whichever test type, with a higher latency to interact with the object or human, and gilts experiencing the startle test first interacted more with the human in all three subsequent tests. Gilts farrowing in crates and pens showed differences in behaviour, most notably, a lower frequency of piglet-directed aggression was seen in pens ($P < 0.05$). Piglet-directed aggression was studied further by comparing gilts that exhibited no aggression, to those showing aggressive behaviour, but no injurious biting, to those causing injury or death. This latter severely aggressive group spent more time alert, piglet focused and standing ($P <0.05$) compared with the other two groups and tended to show greater ($P < 0.1$) contact duration in the first individual pre-pubertal test. Gilts that crushed one or more piglets were slower ($P = 0.038$) to contact either the human or startle object in the first individual test, than those that did not crush. The impact of first individual test on behaviour in subsequent tests indicates that previous test experience could be influencing subsequent behaviour. Differences in gilts

showing severe piglet-directed aggression and between ‘crushers’ and ‘non-crushers’ suggests that it could be possible to use pre-pubertal behaviour to predict maternal ability.

Keywords: Pigs; Behavioural tests; Free farrowing; Maternal behaviour; Savaging; Temperament

1. Introduction

Enclosing sows in crates during farrowing and lactation remains a welfare issue. Despite a growing body of research into alternatives (for reviews see: Baxter et al., 2012; Edwards and Fraser, 1997), no large-scale commercial uptake of crate-free systems on indoor pig farms has occurred, other than in countries where the farrowing crate is banned (Sweden, Switzerland and Norway). The piglet and sow alternative farrowing environment or PigSAFE pen is a crate-free system, designed to improve sow welfare, whilst ensuring ease of management, piglet survival and commercial viability (Baxter et al., 2015, 2011). Results show that the PigSAFE pen produces production figures comparable to those of conventional farrowing crates (Edwards et al., 2012). However, individual variation in sow performance is evident with some individuals performing well, with no pre-weaning losses, whereas others produce high losses (Baxter et al., 2015).

Loose farrowing systems for sows have to be robust enough to cope with individual variation or sensitivity. Thodberg et al. (2002) showed that behaviour during nest-building and farrowing is related to the general reaction pattern during stress, especially in inexperienced gilts. They also showed that the performance reflects an innate pattern of reaction in the individual that can be modified by the environment and previous experience. Another study demonstrated that gilts that savaged their piglets during farrowing were more likely to show ‘shy’ behaviour during a pre-farrowing human approach test (Marchant-Forde, 2002). Sow behaviour during gestation has been related to farrowing behaviour and piglet survival (Lensink et al., 2009a) and gilt behaviour at six months old was shown to be related to farrowing and performance (Lensink et al., 2009b). However, in these studies several correlations were performed and those that were significant were low, ranging in r_s value from -0.19 to 0.29 between behaviour during gestation and farrowing (Lensink et al., 2009b) and -0.27 and 0.41 between behaviour at six months old with farrowing behaviour and performance (Lensink et al., 2009a). Therefore, the authors of these studies concluded that the value of pre-parturition behaviour in predicting farrowing success was not clear and further study is needed. In order to accurately assess temperament, the criteria outlined by Jensen (1995) need to be fulfilled, individuals must: 1) show consistency in reaction when exposed to the same situation; 2) show consistency in reaction across different situations; 3) show a bimodal distribution of responses; and 4) a genetic basis for differences in response must be demonstrated.

If temperament can be successfully assessed and associated with farrowing behaviour, it could be a useful tool in selecting breeding animals for loose-farrowing systems. This study investigated behaviour of gilts during a set of pre-pubertal tests, and then farrowing behaviour was studied as gilts went on to farrow in either conventional farrowing crates or PigSAFE pens.

2. Materials and Methods

2.1. Animals and experimental procedure

All experimental procedures were carried out in compliance with EU Directive 86/609/EEC and were approved by the SRUC Animal Welfare Ethical Review Body (AWERB) before any experiments took place. Twenty-four home bred Large White x Landrace primiparous sows (hereafter, gilts), housed in four groups of six at the SRUC pig research farm in Midlothian, UK were used for this experiment. Initially gilts were housed in their stable groups of six individuals in the commercial finisher shed where they underwent two phases of behavioural testing. The first of these consisted of six tests where the gilt was tested alone (hereafter referred to as individual tests), including three human interaction and three startle object tests, with two tests per day; one in a morning and one in an afternoon session on three days at approximately 20 weeks of age. The second phase consisted of six tests which the gilts underwent in their stable group of six (hereafter referred to as stable group tests), again with two tests per day; one in a morning and one in an afternoon session on three days at approximately 23 weeks of age. At around 25 weeks old, gilts were moved in their groups of six to dry sow accommodation consisting of a straw-bedded area, a dunging passageway and six individual feeding stalls. At around 8 months old, the gilts were artificially inseminated and farrowed in either PigSAFE pens (groups 1 and 4, n = 10) or conventional farrowing crates (groups 2 and 3, n = 11) (for full pen specifications, see Baxter et al., 2015). Of the 24 gilts tested, two did not hold service (i.e. were not pregnant), so did not go on to the second part of the study and due to a power failure, farrowing behaviour is missing for one gilt.

2.2 Individual Tests

Groups 1 and 2, and groups 3 and 4 were tested in two separate batches in October 2009 and January 2010 respectively. Gilts underwent three human interaction and three startle object tests randomly split across three days of the week with a day off in between test days, i.e. each gilt had one test in the morning and one in the afternoon on all of the test days (two tests per day), with a random order of test type (e.g. human-startle-human-startle-startle-human, or any other combination in the six test sessions). Therefore, gilts either had a human interaction (n = 15) or startle object (n = 9) test first on the morning of the first test day. In both morning and afternoon sessions across the three days gilts from either groups’ 1 or 2, or 3 or 4 depending on the test session were alternated for consecutive tests. The test pen for both tests consisted of an empty finisher pen (solid on 3 sides, with metal bars at the back, with no view of other pigs, measuring 3.75 × 2.35 m) located in the same room in the finisher house where the gilts were initially housed. Prior to testing, gilts were habituated to a camera and tripod placed outside their home pen in the days preceding the tests, but gilts were not habituated to the test pen or testing routine. Muck was removed and the pen swept down between each test.

For the human interaction test, the individual gilt was moved into the test pen, the human interactor then climbed into the pen and knelt down in a central position. The test was started when the human was in position and lasted five minutes, before the gilt was returned to her home pen. Evidence suggests that pigs discriminate between familiar and unfamiliar humans using visual cues, including the colour of overalls worn (Koba and Tanida, 1999). Therefore, the human interactor in this study wore red overalls, which was different from the blue overalls routinely worn by stock-people and research staff on the farm.

For the startle object test, an orange bucket was hung on a rope from a pulley system above the centre of the pen. The bucket was pulled towards the ceiling for the start of the test. When ready to start, the test gilt was moved from the home pen towards the test pen and as she crossed into the pen, the bucket was dropped to hit the floor after which, it was immediately raised slightly and the rope tied to leave the bucket hanging approximately 30 centimetres from the floor. The rope was marked to indicate the height at which to hang the bucket. When the bucket was dropped, the stopwatch was started and timed for five minutes after which, the bucket was raised and the gilt returned to her home pen.

2.3. Stable Group Tests

Two weeks later, gilts underwent stable-group testing, again consisting of three test days across a week with a day off in between each test day as before. Gilts underwent three human interaction and three novel object tests randomly split over the three days. The same test pen was used and the tests were video recorded as before.

The human interaction test was similar to the individual tests. Each group of gilts was moved into the test pen, the human interactor then climbed in from the neighbouring pen, and stayed in a kneeling position in the centre. After five minutes, the human left the pen, and the gilts were returned to their home pen. For the novel object test, an orange and white life-saving ring was attached using chains to the bars at the back of the pen, before the gilts were moved into the test pen. The gilts were then moved into the test pen for five minutes and then returned to their home pen. The novel object was cleaned between tests.

2.4. Test Behaviour

All five minute tests were recorded onto DV tape or SD card using either a Canon XM2 or Canon Legria placed on a tripod behind the test pen. Continuous focal observations of gilt behaviour during tests were conducted using The Observer 9.0 XT (Noldus Information Technology, Wageningen, The Netherlands). The duration of contact with the human or object, the latency to contact, and the frequency of contacts were recorded, along with the frequency to contact (nose or root) other parts of the test pen.

2.5. Behaviour at Farrowing

At no more than five days before the expected farrowing date, gilts were moved into their farrowing accommodation. Groups 1 and 4 farrowed in PigSAFE pens, and groups 2 and 3 in conventional farrowing crates. Closed-circuit television (CCTV) cameras (LL20, infra-red cameras, RF concepts, Ireland) were mounted above the pens or crates to record behaviour using GeoVision Digital Surveillance System software (ezCCTV Ltd, Herts, UK). Continuous focal observations were made of gilts for 8 hours from the birth of the first piglet using The Observer XT 9.0. Behaviour recorded included the duration of postures (stand, sit, kneel, lie lateral, lie ventral) and general behaviour, including alert, idle, piglet focused (head and/or ears orientated towards a piglet), straw/floor focused (nosing/rooting the floor/straw). Frequencies of attack/snap behaviour (aggressive interaction towards piglet, without damaging contact), bite (aggressive interaction towards piglet, with damaging contact) and nose (the snout makes contact with a piglet) were also recorded.

2.6. Data analysis

Data were analysed using Genstat 11th Edition and Minitab 15. Results are considered statistically significant at $P \leq 0.05$ and tendencies are discussed at $P \leq 0.1$. Behavioural variables were analysed using mixed models with the with the residual maximum likelihood method (REML) in Genstat. Normally distributed data were analysed using linear mixed models (LMM) and non-normally distributed data with generalised linear mixed models (GLMM) with a Poisson distribution and logarithm as the link function. All REML analyses had group/gilt in the random variation to account for pen level differences and repeated measures.

2.6.1. Behavioural tests

Due to randomisation of the test order for the gilts, some of the gilts had a human interaction (n = 15) and some had a startle object test (n = 9) first. This created an unexpected additional source of variation in the data, in that when observing the gilts' behaviour during these tests, it was noted that the gilts that had the startle object test first had a greater reaction to the startle object when it was their first time in the test arena. Therefore, type of first test (e.g. startle object or human interaction) has been included as a fixed factor, 'first test' in some of the analyses.

Test behaviour variables (contact duration, contact frequency, latency to contact) were first analysed for differences between stable group and individual tests, with 'test mode' (stable group or individual) as a fixed factor. Individual test behaviour was then analysed with 'test type' (human interaction or startle object) × 'test number' (1 to 3) as fixed factors, then startle object and human interaction tests were analysed separately with 'test number' × 'first test' (human or startle) as fixed factors. Stable group test behaviour was then analysed with 'test type' × 'test number' as fixed factors. Spearman's Rank correlation coefficients were calculated between all individual and stable group tests in Minitab for contact duration.

2.6.2. Farrowing behaviour

The gilts were split into three groups based on the aggressive behaviour they exhibited at farrowing: a group which attacked/snapped at, but did not bite piglets (attack, n = 7), a group which attacked/snapped at and bit piglets (bite, n = 5) and a group which did not show aggression towards piglets (none, n = 9). Gilts were also split into a two groups based on crushing behaviour, a groups which killed one or more piglets by crushing (yes, n = 10) and another that did not kill piglets by crushing (no, n = 11). Behaviour for the first eight hours after the birth of the first piglet was analysed with farrowing location (crate or PigSAFE) × piglet aggression (attack, bite, none) as fixed factors, then with crush (yes or no) as a fixed factor.

2.6.3. Testing vs. farrowing

Contact duration and latency to contact the human/startle object for the first individual pre-pubertal test (which was either a startle object or human interaction test) was analysed with piglet aggression group (attack, bite, none) and crush group (yes, no) as fixed factors. Spearman's rank correlations were conducted between gilt testing behaviour and farrowing behavioural variables in Minitab.

3. Results

3.1. Behavioural Tests

Overall, gilts spent a longer period of time interacting with the human or startle/novel object during the individual tests compared to the stable group tests, showed a higher frequency of contacts, but had a higher latency to contact the human or startle/novel object (Table 1).

Insert Table 1

3.1.1. Individual Tests

Figure 1 shows the contact duration and latency to contact for the three individual human interaction and startle object tests, with individuals that had the startle object test first in grey and those that had the human interaction test first in white. No significant differences between contact duration or latency to contact the startle object or human were found ($F_{1,142}$ = 0.46, P = 0.501 and $F_{1,142}$ = 0.52, P = 0.472 respectively).

3.1.2. Individual Startle Object Tests

For the startle object test there was no significant difference in duration of contact across the three tests ($F_{2,,69}$ = 1.33, P = 0.275) but a significant interaction was found for test number × first test ($F_{2,66}$ = 10.05, P < 0.001). For gilts that had the startle object test first the contact duration during the first test was significantly lower than the next two, but gilts assigned to the human interaction test first showed a more consistent duration of contact across the three startle object tests. The latency to contact was significantly different between the three tests ($F_{2,69}$ = 16.37, P < 0.001), with the highest latency being for the first test. The contact latency was also significantly higher for pigs that had a startle test first, compared with the human interaction test first ($F_{1,70}$ = 12.30, P = 0.002). In addition, a significant interaction for test number × first test was found ($F_{2,66}$ = 12.98, P < 0.001). For pigs that had the startle test first, the latency to contact the object was almost three times higher for the first test compared to the second and third, but for gilts that had the human interaction test first the latency was more consistent, with the highest latency for the first test, getting slightly lower on the second and third tests.

3.1.3. Individual Human Interaction Tests

There was no significant difference in contact duration across the three human interaction tests ($F_{2,69}$ = 0.48, P = 0.620). In contrast to the startle object test, significantly higher contact duration was found for gilts that had the startle test first ($F_{1,70}$ = 7.54, P = 0.012) and no test number × first test interaction ($F_{2,66}$ = 1.89, P = 0.16) indicates that this difference is consistent across the three tests. The latency to contact the human was significantly different across the three tests ($F_{2,69}$ = 5.11, P = 0.010) and significantly higher if the first test was a human interaction test ($F_{1,70}$ = 7.19, P = 0.015) but there was no significant test number × first test interaction ($F_{2,66}$ = 2.30, P = 0.112) because the first human interaction test was higher than the second and third whether the gilts had a startle object test or human interaction test first.

3.1.4. Stable Group Tests

No significant difference in the contact duration or latency were found between the novel object or human interaction stable group tests ($F_{1,142}$ = 0.35, P = 0.555 and $F_{1,142}$ = 0.80, P = 0.37 respectively) (Figure 2). A signifcant test type × test number interaction was found for contact duration ($F_{2,138}$ = 7.42, P < 0.001) as the novel object test had a higher contact duration for test one comapared to tests two and three, whereas contact duration was more consistent across the three human interaction tests.

3.1.5. Between test relationships

Table 2 shows correlations between contact duration for the three individual human interaction and startle object tests, the three group human interaction and novel object tests, and between the individual and group tests. Gilts showed some consitency in the duration of contact in the human interaction tests, with significant positive correlations between the three individual tests, the group tests and between the individual and group tests.

Insert Table 2

3.2. Farrowing

On average the gilts' had 11.27 ± 0.73 piglets born alive (C = 12.72 ± 0.43, PS = 9.83 ± 1.29), 0.64 ± 0.20 born dead (C = 0.64 ± 0.24, PS = 0.64 ± 0.34) and live born mortality was 16.91 ± 3.21 % (C = 17.31 ± 4.90, PS = 16.50 ± 4.37).

3.2.1. Behaviour: Crates vs. PigSAFE pens

Crate gilts spent a higher percentage of time engaged in piglet focused behaviour (C = 11.0 ± 2.0; PS = 4.4 ± 1.1, $W_{1,19}$ = 9.33, P = 0.038) and PS gilts spent more time alert (C = 5.0 ± 1.1; PS = 9.2 ± 2.9, $W_{1,19}$ = 6.61, P = 0.022) and straw/floor focused (C = 1.0 ± 0.3; PS = 2.2 ± 0.7, W = 11.45, P = 0.004). PS gilts spent more time standing than C gilts (C = 3.1 ± 1.2; PS = 5.5 ± 1.7, $W_{1,19}$ = 6.36, P = 0.024), with no other differences in posture. Crate gilts showed a higher frequency of attack/snap (C = 13.6 ± 4.8; PS = 6.2 ± 2.4, $W_{1,19}$ = 10.37, P = 0.006) and biting behaviour (C = 4.0 ± 2.4; PS = 1.0 ± 0.6, $W_{1,19}$ = 4.58, P = 0.05). No other significant differences in the behaviour between C and PS gilts were found.

3.2.2. Savaging and crushing

Of the 22 gilts that went on to farrow, 10 killed one or more piglets by crushing (45.5 %) and 12 did not kill any piglets by crushing. Twelve (57.1 %) out of the 21 gilts showed some kind of aggression, in the form of attacking/snapping at or biting piglets, six from crates and six from pens, five (23.8 %) of which killed one or more piglets (C = 3, PS = 2) and two (9.5 %) showed biting behaviour towards piglets, causing injuries but not mortality. Attack/snap behaviour was significantly more frequent in crates than PigSAFE pens (see previous section), and the frequencies of aggressive events reduced sooner in PigSAFE pens compared to crates (Figure 3), although a small peak in aggressive behaviour was seen in both environments at seven hours after the birth of the first piglet.

Farrowing behaviour was compared between the three aggression groups (attack, bite or none) (Table 3). Several significant differences in behaviour were observed for these three groups of gilts, including the duration of time spent alert and piglet focused, which were higher for the bite group, compared to the other two groups and idle, which was lower for the bite group. Significant differences were also seen for the postures stand and sit, which were higher and lie lateral, which was lower for the bite group, compared to the attack/snap and no aggression groups. No significant differences in behaviour for the first eight hours after the birth of the first piglet were found between gilts which did or did not kill piglets by crushing, but there was a tendency for gilts that crushed piglets to spend less time in piglet focused behaviour (Table 3).

Insert Table 3

3.3. Testing vs. Farrowing

Gilts demonstrating different levels of aggression towards their piglets (attack, bite, none), tended to differ for contact duration ($F_{2,18}$ = 2.75, *P* = 0.095) during the first individual pre-pubertal test (startle object or human interaction). Post hoc analysis showed that the attack and no aggression group did not differ ($T_{1,14}$ = 0.37, *P* = 0.744), whereas the attack and bite and bite and no aggression group tended to differ ($T_{1,10}$ = 2.04, *P* = 0.069 and $T_{1,12}$ = 2.00, *P* = 0.065 respectively; Figure 4a). There was no significant difference between piglet aggression groups for the latency to contact the human/startle object during the first behavioural test ($W_{2,18}$ = 3.56, *P* = 0.202). For the gilts grouped on crushing, there was no significant difference in the duration of contact for the first individual behavioural test ($F_{1,19}$ = 2.45, *P* = 0.135), but a significant difference for the latency to contact the human or startle object was found ($W_{1,19}$ = 5.28, *P* = 0.038; Figure 4b). Spearman's rank correlations between testing behaviour and farrowing behaviour showed no pattern of significant correlation.

4. Discussion

4.1. Behavioural tests

The results from the individual tests indicate that gilts with the startle object test first and gilts that had the human interaction test first behaved differently in pre-pubertal tests, indicating that previous test experience is influencing behaviour in subsequent tests. In a previous study, pigs with regular exposure to humans were quicker to approach a novel object, although pigs with regular exposure to novel objects were not quicker to approach a human, compared with pigs which had no previous experience of either human contact or novel objects (Hemsworth et al., 1996). Gilts interacted with the novel object longer during the first stable group novel object test, compared to the remaining two tests, which is unsurprising given that the novel object was different for the stable group tests. As in this study, a previous study in which pigs underwent several behavioural tests also showed a habituation effect, as latency to contact decreased with subsequent tests (Brown et al., 2009).

Some consistency in behaviour was shown between individual and stable group human interaction tests. This is similar to previous studies, where correlations were found between tests with similar stimuli (Janczak et al., 2003b; Lawrence et al., 1991; Spoolder et al., 1996). By contrast, a study of finisher pigs found consistency in response to different test types as well as over time (Brown et al., 2009) and prepubertal gilts showed a general reaction pattern across different non-social situations (Thodberg et al., 1999). In other situations, male and female growing pigs showed consistency in aggression and mounting behaviour (Clark and D'Eath, 2013) and at farrowing 14 % of sows that savaged as gilts, savaged on the second parity, compared with only 0.8 % of sows, which did not savage as gilts (Harris et al., 2003). Jensen et al. (1995), however, failed to find consistency in the undisturbed behaviour of piglets pre-weaning. Greater consistency in response to the tests used in the current study may have been found if the test order was not randomised and the gilts' were habituated to the test arena beforehand, so that they were responding to the novelty of the startle object and human, rather than the arena. However, according to the properties outlined by Jensen, (1995), the data in this study do not provide evidence of distinct coping strategies. In a critical evaluation of fear tests, Forkman et al.

(2007) concluded that fear tests for pigs are not well validated as inter-test correlations were low for the various tests that have been used, which is supported in this study.

4.2. Farrowing

An interesting finding from this study is that gilts in PigSAFE pens showed fewer aggressive interactions towards piglets compared with gilts in crates. The consequences of piglet-directed aggression could be much more severe in loose-farrowing systems and a previous study found that more individuals exhibited piglet-directed aggression in farrowing pens compared to crates (Marchant-Forde, 2002). Wild boar have been observed to exhibit piglet-directed aggression at high levels when farrowing in captivity suggesting that the environment, rather than the process of domestication may be influencing this unwanted behaviour (Harris et al., 2001). Reduced piglet-directed aggression was seen when gilts were provided with continuous light, which the authors suggested could enable the gilts to see the piglets better, reducing their alarm or fear as piglets approach (Harris and Gonyou, 2003). Stress, pain, or the inability to cope with confinement could also negatively affect gilts behaviour leading to piglet-directed aggression (Ahlström et al., 2002; Cronin et al., 1996; Jarvis et al., 1998). Perhaps the ability of the gilts housed in PigSAFE pens to interact properly with piglets, enabling the development of mother-young relationships to be faster than those in crates, could have reduced piglet-directed aggression. In this study PS gilts exhibited more nose contact with piglets, but had a lower duration of piglet-focused behaviour (where the gilts head and/or ears are orientated towards a piglet but with no physical contact), which could be an indication of the need, but inability of gilts in crates to interact properly with piglets.

A study of piglet-directed aggression in wild boar separated individuals into three groups based on aggression towards piglets, including none (0), moderate (1), where there was some aggression not resulting in injury and severe (2) where one or more piglets were killed or intervention was needed to protect the piglets (Harris et al., 2001). An early study of sow parturition also observed aggressive behaviour, where the sows appeared defensive, backing away from piglets and attempting to bite, but also extreme aggression where sows actively attacked piglets in the farrowing pen (Randall, 1972). Gilts in this study were also grouped based on piglet-directed aggression. Another interesting outcome from this study is that gilts exhibiting severe aggression resulting in the death of piglets showed several differences in behaviour compared with the other two groups, although these results should be treated with some caution due to low numbers of animals. Harris et al. (2001) also found that wild boar gilts with a piglet aggression score of two, differed from those scoring one or zero. In other studies savaging sows have been shown to be more restless during parturition, exhibiting more posture changes, standing behaviour and were more responsive to their piglets (Ahlström et al., 2002; Chen et al., 2008).

Behaviour after the onset of farrowing was also compared between gilts that crushed one or more piglets to those that did not, but no clear behavioural differences were demonstrated. A previous study comparing ‘crushers’ with ‘non-crushers’ showed ‘non-crushers’ to have a better mothering style, including nosing the piglets more when changing posture and reacting sooner to piglet distress calls by directing attention towards piglets (Andersen et al., 2005). Crushing has not been directly related to posture or posture changes, but is related to the maternal ability of the sow to lie carefully and respond to piglet screams (e.g. Andersen et al., 2005; Wischner et al., 2010, 2009). Behavioural differences may have been seen in this study if more detailed maternal behaviour was measured.

4.3. Testing vs. farrowing

No significant pattern of correlation was found between behaviour during the tests and at farrowing. However, when the contact duration and latency for the first individual behavioural test were compared between piglet aggression groups, and for ‘crushers’ versus ‘non-crushers’, some differences were found. Firstly, the group showing severe piglet-directed aggression tended to have longer contact duration than the other two groups, and secondly, gilts that crushed piglets had a longer latency to contact the startle object or human in the first behavioural test, compared with those that did not crush. These differences are small and should be treated with caution, but will be discussed in relation to previous research.

In contrast to the finding in this study, a previous study found that gilts which killed piglets by savaging showed more shy behaviours during a pre-farrowing human approach test, including a longer latency to interact with the human and with fewer interactions (Marchant-Forde, 2002). The same study found that gilts which were dangerously aggressive towards the stock-person showed more bold behaviours during this test. Behaviour was compared between savaging and non-savaging sows around parturition and results showed that savaging sows showed more posture changes from before farrowing and during the piglet expulsion phase (Chen et al., 2008). The authors suggested that although the aetiology of this abnormal behaviour remains to be found, it could be a more generalised behavioural pathology including increased excitability, which is not specifically piglet-related (Chen et al., 2008), this would fit with the increased contact duration during behavioural tests found in the current study. In a study of another abnormal, unwanted behavioural problem in pigs, tail biting, researchers found that biters interacted more with enrichment devices, compared with victims and control pigs (Zonderland et al., 2011). This again, fits with the theory of a behavioural pathology related to increased excitability.

Again, in contrast to the current study, a previous study found that the gilts with a shorter latency to interact with a novel object at six months of age crushed more piglets (Lensink et al., 2009b). However, this study also found that the escape behaviour from a human entering the home pen at six months old and the withdrawal response when sows were approached from the front of the farrowing crate tended to correlate positively with piglet crushing and nervousness around farrowing significantly correlated with crushing (Lensink et al., 2009b). Another study found that a high withdrawal response of sows to being touched by a human during feeding, two weeks before farrowing positively correlated with the number of piglets crushed (Lensink et al., 2009a). In the latter study, the authors suggested that high fearfulness was associated with piglet crushing, which would fit with the data in this study, where crushers showed a longer latency to contact the human or startle object during the first pre-pubertal test.

Relationships between crushing of piglets and behaviour during a human interaction and novel object test at eight weeks old have not been found, however, 'fear of humans', but not 'novelty induced anxiety' was related to reproductive parameters, with less fearful sows demonstrating higher reproductive success (Janczak et al., 2003a), a result also found in earlier studies relating to fear of humans (Hemsworth et al., 1989, 1981). In another study where pre-pubertal gilts underwent behavioural tests, those which were calm during the stressful test situation, timed their nest building more optimally and behavioural activity during tests correlated with being active during farrowing (Thodberg et al., 2002). Andersen et al., (2005) found that non-crushers performed more nest building behaviour from 8 to 6 hours pre-farrowing compared with crushers, but the opposite was found in the last hour before farrowing when crushers tended to perform more nest-building activity.

As with previous work (Lensink et al., 2009a;b), the link between pre-pubertal and farrowing behaviour in this study is not completely clear and the unexpected additional source of variation created by the test regime used in this study and low sample size, limited the ability to explore these connections using multivariate statistical techniques (Budaev, 2010). A number of factors influence good maternal behaviour, but the results of this study, along with others (Lensink et al., 2009a, 2009b; Marchant-Forde, 2002; Thodberg et al., 2002), do indicate that it could be possible to predict good maternal behaviour and select gilts to optimise performance in loose-farrowing systems. However, more work is needed to provide additional information, perhaps using more carefully-selected measures, larger sample sizes and multivariate statistical techniques, to better predict breeding sow performance. Information provided here gives a basis on which to build for future studies in this area of research.

5. Conclusions

Gilt behaviour during pre-pubertal individual tests was influenced by the test type first experienced; demonstrating that behavioural response to novel situations is likely to be sensitive to several factors. Lower frequencies of piglet-directed aggression seen in PigSAFE pens is an interesting result and could be due to a greater ability to display normal maternal behaviour. Correlation between pre-pubertal test behaviour and farrowing behaviour was not found. However, differences in behaviour for the first individual test were found for gilts showing severe piglet-directed aggression and between those that crushed or did not crush piglets, indicating that it could be possible to use pre-pubertal behaviour to predict maternal ability, but a better measure; perhaps using response to novelty and a multivariate approach is needed.

Acknowledgements

The authors are grateful to the Department for Environment, Food and Rural Affairs (Defra) who funded the main "PigSAFE" project in which this study was conducted. Authors also receive funding from the Scottish Government. We are also grateful to Marianne Farish for being the human in the human interaction tests, Mhairi Jack for providing technical assistance and farm staff Peter Finnie and Phil O'Neil for looking after the animals.

References

Ahlström, S., Jarvis, S., Lawrence, A.B., 2002. Savaging gilts are more restless and more responsive to piglets during the expulsive phase of parturition. Appl. Anim. Behav. Sci. 76, 83–91.

Andersen, I.L., Berg, S., Bøe, K.E., 2005. Crushing of piglets by the mother sow (Sus scrofa)—purely accidental or a poor mother? Appl. Anim. Behav. Sci. 93, 229–243.

Baxter, E.M., Adeleye, O.O., Jack, M.C., Farish, M., Ison, S.H., Edwards, S.A., 2015. Achieving optimum performance in a loose-housed farrowing system for sows: the effects of space and temperature. Appl. Anim. Behav. Sci. in press.

Baxter, E.M., Lawrence, A.B., Edwards, S.A., 2011. Alternative farrowing systems: design criteria for farrowing systems based on the biological needs of sows and piglets. Animal 5, 580–600.

Baxter, E.M., Lawrence, A.B., Edwards, S.A., 2012. Alternative farrowing accommodation: welfare and economic aspects of existing farrowing and lactation systems for pigs. Animal 6, 96–117.

Brown, J.A., Dewey, C., Delange, C.F.M., Mandell, I.B., Purslow, P.P., Robinson, J.A., Squires, E.J., Widowski, T.M., 2009. Reliability of temperament tests on finishing pigs in group-housing and comparison to social tests. Appl. Anim. Behav. Sci. 118, 28–35.

Chen, C., Gilbert, C., Yang, G., Guo, Y., Segondspichon, a, Ma, J., Evans, G., Brenig, B., Sargent, C., Affara, N., 2008. Maternal infanticide in sows: Incidence and behavioural comparisons between savaging and non-savaging sows at parturition. Appl. Anim. Behav. Sci. 109, 238–248.

Clark, C.C.A., D'Eath, R.B., 2013. Age over experience: Consistency of aggression and mounting behaviour in male and female pigs. Appl. Anim. Behav. Sci. 147, 81–93.

Cronin, G., Simpson, G., Hemsworth, P., 1996. The effects of the gestation and farrowing environments on sow and piglet behaviour and piglet survival and growth in early lactation. Appl. Anim. Behav. … 46, 175–192.

Edwards, S., Fraser, D., 1997. Housing systems for farrowing and lactation. Pig J. 39, 77–89.

Edwards, S.A., Brett, M., Ison, S.H., Jack, M.C., Seddon, Y.M., Baxter, E.M., 2012. Design principles and practical evaluation of the PigSAFE free farrowing pen, in: 4th European Symposium on Porcine Health Management, Ghent, Belgium. p. 113.

Forkman, B., Boissy, a, Meuniersalaun, M., Canali, E., Jones, R., 2007. A critical review of fear tests used on cattle, pigs, sheep, poultry and horses. Physiol. Behav. 92, 340–374.

Harris, M., Bergeron, R., Gonyou, H., 2001. Parturient behaviour and offspring-directed aggression in farmed wild boar of three genetic lines. Appl. Anim. Behav. Sci. 74.

Harris, M., Gonyou, H., 2003. Savaging behaviour in domestic gilts: A study of seven commercial farms. Can. J. Anim. Sci. 9.

Harris, M.J., Li, Y.Z., Gonyou, H.W., 2003. Savaging behaviour in gilts and sows. Can. J. Anim. Sci. 819–821.

Hemsworth, P., Barnett, J., Coleman, G., Hansen, C., 1989. A study of the relationships between the attitudinal and behavioural profiles of stockpersons and the level of fear of humans and reproductive performance of commercial pigs. Appl. Anim. Behav. Sci. 23, 301–314.

Hemsworth, P., Brand, A., Willems, P., 1981. The behavioural response of sows to the presence of human beings and its relation to productivity. Livest. Prod. Sci. 8, 67–74.

Hemsworth, P.H., Price, E.O., Borgwardt, R., 1996. Behavioural responses of domestic pigs and cattle to humans and novel stimuli. Appl. Anim. Behav. Sci. 50, 43–56.

Janczak, A.M., Pedersen, L., Rydhmer, L., Bakken, M., 2003a. Relation between early fear- and anxiety-related behaviour and maternal ability in sows. Appl. Anim. Behav. Sci. 82, 121–135.

Janczak, A.M., Pedersen, L.J., Bakken, M., 2003b. Aggression, fearfulness and coping styles in female pigs. Appl. Anim. Behav. Sci. 81, 13–28.

Jarvis, S., Lawrence, A.B., McLean, K.A., Chirnside, J., Deans, L.A., Calvert, S.K., 1998. The effect of environment on plasma cortisol and beta-endorphin in the parturient pig and the involvement of endogenous opioids. Anim. Reprod. Sci. 52, 139–51.

Jensen, P., 1995. Individual variation in the behaviour of pigs—noise or functional coping strategies? Appl. Anim. Behav. Sci. 44, 245–255.

Jensen, P., Forkman, B., Thodberg, K., Kijster, E., 1995. Individual variation and consistency in piglet behaviour 45, 43–52.

Koba, Y., Tanida, H., 1999. How do miniature pigs discriminate between people? The effect of exchanging cues between a non-handler and their familiar handler on discrimination. Appl. Anim. Behav. Sci. 61, 239–252.

Lawrence, a. B., Terlouw, E.M.C., Illius, a. W., 1991. Individual differences in behavioural responses of pigs exposed to non-social and social challenges. Appl. Anim. Behav. Sci. 30, 73–86.

Lensink, B., Leruste, H., De Bretagne, T., Bizeray-Filoche, D., 2009a. Sow behaviour towards humans during standard management procedures and their relationship to piglet survival. Appl. Anim. Behav. Sci. 119, 151–157.

Lensink, B., Leruste, H., Le Roux, T., Bizeray-Filoche, D., 2009b. Relationship between the behaviour of sows at 6 months old and the behaviour and performance at farrowing. Animal 3, 128–34.

Marchant-Forde, J.N., 2002. Piglet- and stockperson-directed sow aggression after farrowing and the relationship with a pre-farrowing, human approach test. Appl. Anim. Behav. Sci. 75, 115–132.

Randall, G., 1972. Observations on Parturition in the Sow I. Factors Associated with the Delivery of the Piglets and their Subsequent Behaviour. Vet. Rec. 90, 178–182.

Spoolder, H.A.M., Burbidge, J.A., Lawrence, A.B., Simmins, P.H., Edwards, S.A., 1996. Individual behavioural differences in pigs: intra-and inter-test consistency. Appl. Anim. Behav. Sci. 49, 185–198.

Thodberg, K., Jensen, K.H., Herskin, M.S., 1999. A general reaction pattern across situations in prepubertal gilts. Appl. Anim. Behav. Sci. 63, 103–119.

Thodberg, K., Jensen, K.H., Herskin, M.S., 2002. Nest building and farrowing in sows: relation to the reaction pattern during stress, farrowing environment and experience. Appl. Anim. Behav. Sci. 77, 21–42.

Wischner, D., Kemper, N., Stamer, E., Hellbruegge, B., Presuhn, U., Krieter, J., 2009. Characterisation of sows' postures and posture changes with regard to crushing piglets. Appl. Anim. Behav. Sci. 119, 49–55.

Wischner, D., Kemper, N., Stamer, E., Hellbrügge, B., Presuhn, U., Krieter, J., 2010. Pre-lying behaviour patterns in confined sows and their effects on crushing of piglets. Appl. Anim. Behav. Sci. 122, 21–27.

Zonderland, J.J., Schepers, F., Bracke, M.B.M., den Hartog, L. a, Kemp, B., Spoolder, H. a M., 2011. Characteristics of biter and victim piglets apparent before a tail-biting outbreak. Animal 5, 767–75.

Table 1

Mean ± Standard Error for variables measured in both individual human interaction and startle response tests and group human interaction and novel object tests with group vs. individual effects and *P* values

	Individual Test		Group Test		Group vs. Individual
Behaviour	Human	Startle	Human	Novel Object	Effect, *P* value
Contact duration (s)	132.84 ± 6.97	126.57 ± 8.84	105.98 ± 6.66	110.97 ± 5.98	$F_{1,286} = 8.73$, $P = 0.003$
Contact frequency	9.86 ± 0.43	14.14 ± 0.96	7.82 ± 0.37	7.10 ± 0.31	$F_{1,286} = 59.03$, $P < 0.001$
Latency to contact (s)	18.73 ± 4.74	29.42 ± 14.29	7.78 ± 1.48	10.63 ± 2.53	$W_{1,286} = 6.55$, $P = 0.011$

Table 2

Spearman's rank correlation coefficients (r_s) and *P* values for contact durations between a) the three individual human interaction (IH1, IH2, IH3) and startle object (S1, S2, S3) tests; b) the three group human interaction (GH1, GH2, GH3) and novel object tests (NO1, NO2, NO3) and c) between the group and individual tests.

a) Individual Tests : r_s, *P*

	IH1	IH2	IH3	S1	S2
IH2	0.370, 0.075				
IH3	**0.438, 0.032**	**0.507, 0.012**			
S1	-0.354, 0.097	-0.339, 0.113	-0.213, 0.329		
S2	-0.028, 0.896	-0.157, 0.464	-0.189, 0.377	0.359, 0.092	
S3	0.002, 0.993	-0.327, 0.127	0.091, 0.679	0.210, 0.348	0.397, 0.061

b) Group Tests: r_s, *P*

	GH1	GH2	GH3	NO1	NO2
GH2	0.374, 0.126				
GH3	**0.638, 0.004**	**0.783, <0.001**			
NO1	-0.029, 0.909	-0.177, 0.407	-0.250, 0.239		
NO2	0.364, 0.138	0.224, 0.293	0.025, 0.908	0.310, 0.140	
NO3	-0.195, 0.433	**-0.456,0.025**	**-0.445, 0.029**	0.282, 0.182	0.049, 0.818

c) Group vs. individual tests: r_s, *P*

	GH1	GH2	GH3	NO1	NO2	NO3
IH1	0.225, 0.370	0.023, 0.917	-0.115, 0.594	0.021, 0.924	0.183, 0.391	0.259, 0.222

IH2	**0.577, 0.012**	0.111, 0.606	0.343, 0.101	-0.242, 0.254	-0.100, 0.642	0.150, 0.485
IH3	**0.486, 0.041**	**0.446, 0.029**	**0.515, 0.010**	-0.244, 0.251	0.030, 0.889	-0.145, 0.499
S1	-0.025, 0.924	0.030, 0.893	0.185, 0.398	-0.110, 0.618	0.006, 0.978	**-0.415, 0.049**
S2	0.057, 0.824	-0.165, 0.442	0.081, 0.708	-0.001,0.998	-0.142, 0.509	-0.142, 0.508
S3	-0.147, 0.573	0.148, 0.499	0.018, 0.935	0.373, 0.080	0.044, 0.844	-0.237, 0.276

Table 3

Mean ± standard error for behavioural variables measured during farrowing, with gilts grouped by aggression towards piglets during farrowing (attack, bite, none) and crushing (yes or no) effects and *P* values for differences between these groups

	Piglet aggression				Crushing		
Behaviour	Attack (n = 5)	Bite (n = 7)	None (n = 9)	Effect, *P* value	Yes (n = 10)	No (n = 11)	Effect, *P* value
Alert	5.79 ± 1.86	11.59 ± 3.77	4.18 ± 1.22	$W_{2,18} = 7.87$, $P = 0.044$	5.99 ± 2.53	7.82 ± 2.53	$W_{1,19} = 0.35$, $P = 0.56$
Idle	87.84 ± 2.98	73.32 ± 3.95	88.56 ± 2.10	$W_{2,18} = 15.87$, $P = 0.005$	85.49 ± 1.90	81.67 ± 3.76	$W_{1,19} = 0.66$, $P = 0.43$
Piglet focused	5.37 ± 1.49	12.67 ± 2.71	5.50 ± 1.56	$W_{2,18} = 11.17$, $P = 0.018$	6.38 ±1.51	8.97 ± 2.09	$W_{1,19} = 3.73$, $P = 0.070$
Straw/floor focused	0.91 ± 0.52	2.19 ± 0.65	1.47 ± 0.63	$W_{2,18} = 2.34$, $P = 0.34$	1.79 ± 0.62	1.42 ± 0.46	$W_{1,19} = 0.04$, $P = 0.85$
Stand	1.90 ± 1.14	8.11 ± 2.26	2.54 ± 0.59	$W_{2,18} = 11.09$, $P = 0.017$	3.11 ± 0.69	5.09 ± 1.67	$W_{1,19} = 1.07$, $P = 0.32$
Sit	0.93 ± 0.24	3.57 ± 0.86	1.73 ± 0.62	$W_{2,18} = 5.29$, $P = 0.11$	1.81 ± 0.61	2.41 ± 0.64	$W_{1,19} = 0.43$, $P = 0.52$
Lie Lateral	88.71 ± 2.89	75.00 ± 4.36	89.51 ± 2.35	$W_{2,18} = 9.93$, $P = 0.022$	86.76 ± 3.74	82.78 ± 3.74	$W_{1,19} = 0.69$, $P = 0.42$
Lie Ventral	8.33 ± 1.99	13.10 ± 4.00	6.01 ± 1.59	$W_{2,18} = 3.45$, $P = 0.21$	8.10 ± 1.69	9.52 ± 2.63	$W_{1,19} = 0.18$, $P = 0.68$
Posture changes	73.60 ± 10.31	115.86 ± 16.29	83.44 ± 14.27	$W_{2,18} = 4.45$, $P = 0.15$	95.22 ± 11.36	89.42 ± 13.70	$W_{1,19} = 0.10$, $P = 0.67$

Fig. 1. Contact duration (s) and latency to contact (s) for the three individual startle response and three individual human interaction tests, separated by the gilts' first test: startle response (n = 9, grey) or human interaction (n = 15, white)

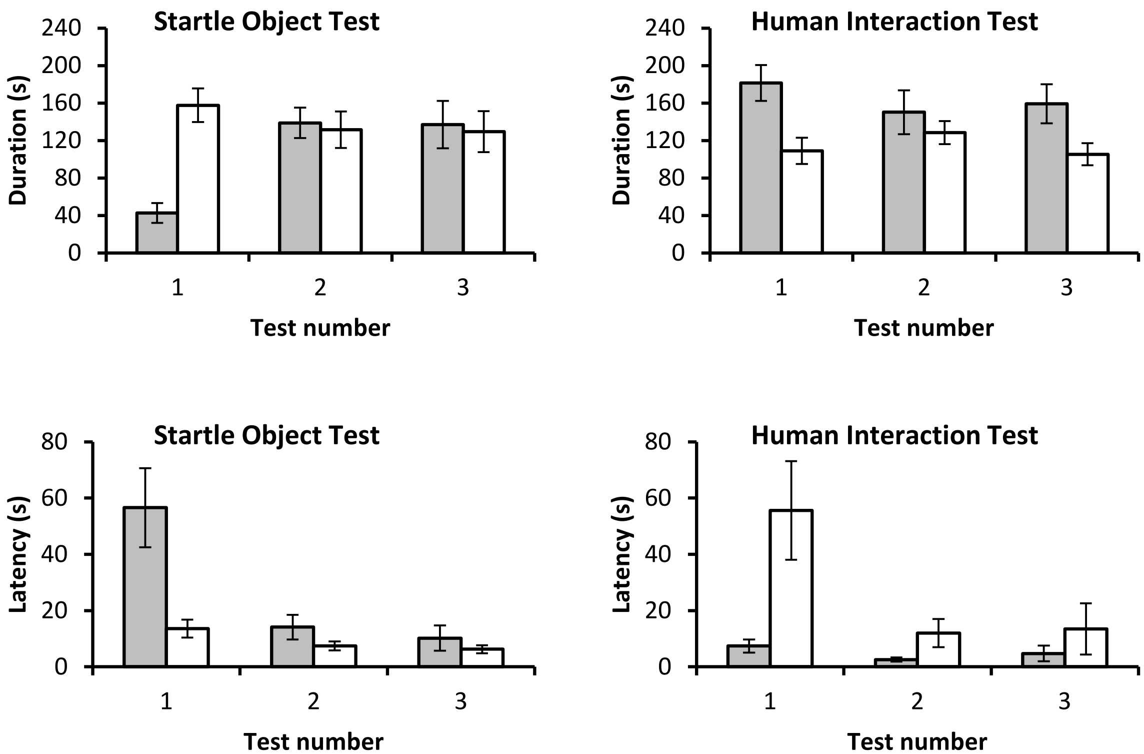

Fig. 2. Mean ± SE for the duration of contact (a) and latency to contact (b) for the first, second, and third group human interaction (grey) and novel object (white) tests

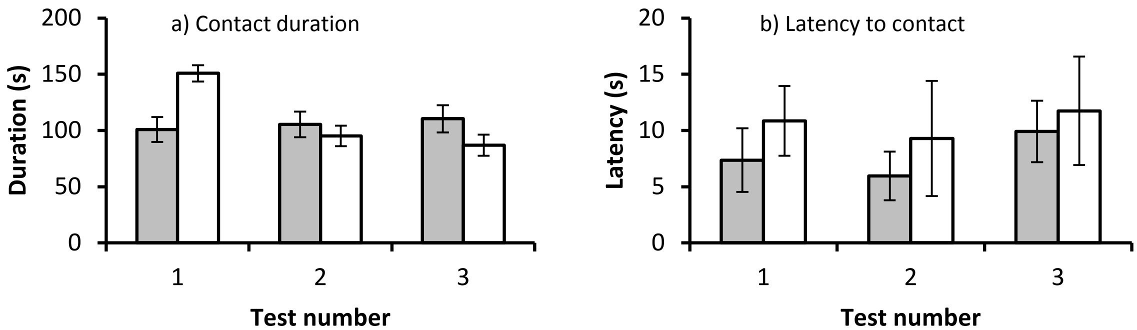

Fig. 3. Frequencies of aggressive events (attack/snap and bite) by hour of observation for gilts farrowing in crates (n = 6) or PigSAFE pens (n = 6)

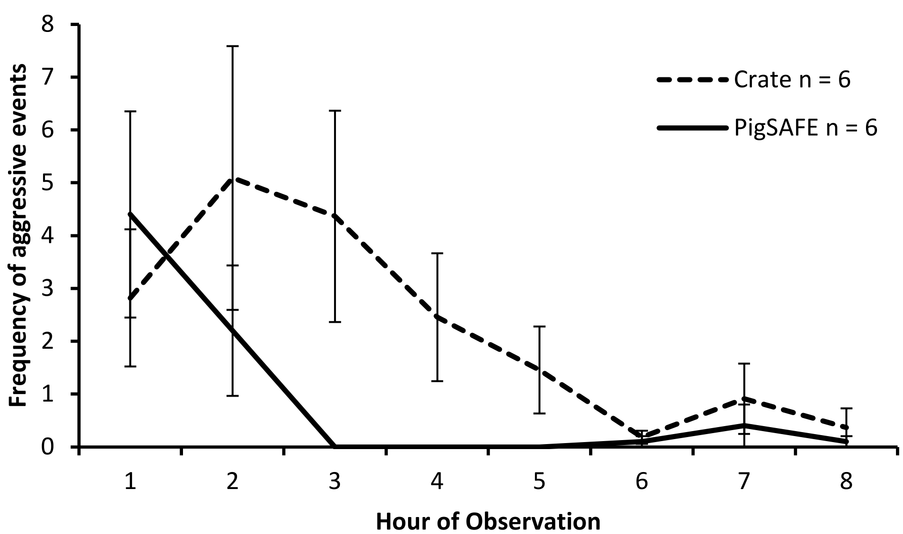

Fig. 4. Contact duration and the latency to contact (seconds) for the first individual behavioural test by a) piglet aggression groups: attack (n = 5), bite (n = 7), and none (n = 9) and b) crush groups: yes (n = 10), no (n = 12)